<Division of Multidisciplinary Chemistry> Polymer Materials Science

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- Polymer Materials Science -

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Scope of Research

The structure and molecular motion of polymer substances are studied using mainly scattering methods such as neutron, X-ray and light with intension of solving fundamentally important problems in polymer science. The main projects are: the mechanism of structural development in crystalline polymers from the glassy or molten state to spherulites; the dynamics in disordered polymer materials including low-energy excitation or excess heat capacity at low temperatures, glass transition and local segmental motions; formation processes and structure of polymer gels; the structure and molecular motion of polyelectrolyte solutions; the structure of polymer liquid crystals.

Research Activities (Year 2004)

Presentations

Thermal Expansion and Contraction of Polymer Thin Films, Kanaya T, Workshop on Auxetics and Related Systems, Poznan, Poland, 27 - 30 June (invited).

Reduced Viscosity of Linear and Spherical Polyelectrolyte Solutions: Differences and Similarities, Nishida K, Kanaya T, Kaji K, International Symposia on Polyelectrolytes, Massachusetts, 15 June.

Structure Formation of Polyelectrolyte Solutions by Coulombic Interactions, Nishida K, Kanaya T, Kaji K, 2004 Spring Meeting, the Physical Society of Japan, Fukuoka, 28 March (invited).

Structual Analysis of Drawing Polyethylene Blends with Ultra High Molecular Weight Component, Matsuba G, Ogino Y, Fukushima H, Kanaya T, Nishida K, 228th ACS National Meeting, Philadelphia, PA, USA, 24 August.

Neutron-Spin Echo Studies on Three Types of Poly(vinyl alcohol) Gels, Takahashi N, Kanaya T, Nishida K, Kaji K, UK-JPN Polymer Workshop, Kyoto, 1 April.

Crystallization of Isotactic Polypropylene under Shear Flow, Ogino Y, Matsuba G, Nishida K, Kanaya T, OUMS' 04, Osaka, 12 July.

Effect of Tacticity of Isotactic Polypropylene on Mesomorphic Phase Formation and Crystallization, Konishi T, Nishida K, Matsuba G, Kanaya T, Society of Polymer Science, Japan, Meeting, Soc. Polym. Sci, Hyogo, 25 May.

Dynamics of Polymer Thin Films in Picosecond Region as Studied by Inelastic and Quasielastic Neutron Scattering, Inoue R, Nishida K, Kanaya T, Tsukushi I, Shibata K, Autumn Meeting, Physical Society of Japan, Aomori, 12 September.

Effect of Ultra High Molecular Weight Component in Crystallization of Polyetylene under Shear Flow, Sakamoto S, Kanaya T, Nishida K, Matsuba G, 53th Symposium on Macromolecules, Hokkaido, September 16.

Grants

Kanaya T, Nishida K, Polymer Crystallization under

Nanoscale Dynamics of Polymer Gels

Neutron spin-echo (NSE) technique is a unique tool to study dynamics in nanometer scale. We have investigated dynamic and static fluctuations in three types of poly(vinyl alcohol) (PVA) gels to elucidate the heterogeneity in nanometer scale using NSE spectrometer in JRR-3M reactor in Tokai (Fig. 1). The first one was a PVA gel in a mixture of deuterated dimethyl sulfoxide (DMSO-d_6) and D_2O with volume fraction of DMSO-d_6 being 0.6. On the basis of NSE results, small-angle neutron scattering (SANS) intensity was divided into static and dynamic fluctuations to find that the static fluctuations were dominant in the present Q range (Fig. 2). The second one was PVA in aqueous borax solution. The intermediate scattering functions of the gel as well as the sol were well described by Zimm mode and gel mode in Q regions above and below a critical value Q_c, corresponding to the correlation length of the network. The last one was the chemically cross-linked PVA gel. The intermediate scattering function was also described by Zimm mode in a short-time region, suggesting that the gel behaves like the sol. However, in a long-time region, the data points deviated from Zimm function, suggesting that the long-time dynamics was restricted by the cross-links.

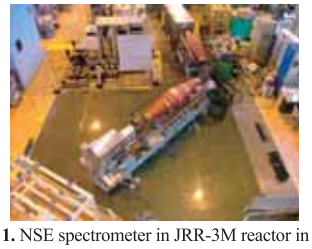

Figure 1. NSE spectrometer in JRR-3M reactor in Tokai.

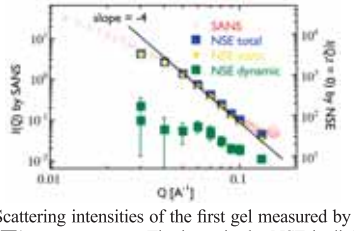

Figure 2. Scattering intensities of the first gel measured by SANS-U (+) and NSE (■) spectrometers. The intensity by NSE is divided into the static (●) and dynamic (■) fluctuations.

Mesomorphic Phase Formation of Isotactic Polypropylene

It is well known that isotactic polypropylene (iPP) forms an intermediate structure between crystal and amorphous when molten iPP is rapidly quenched below 0°C. The structure is referred to as "mesomorphic phase". The term has sometimes been used to describe structures of highly imperfect crystals. However, this is not relevant to the mesomorphic phase of iPP. Only iPP with high tacticity (iPP-HT) can form the mesomorphic phase by the rapid quench, whereas iPP with low tacticity (iPP-LT) cannot form the mesomorphic phase but it crystallizes by the same rapid quench (Fig. 3a). If the mesomorphic phase related to the imperfectness of crystal, the decrease of tacticity should enhance the formation of the mesomorphic phase. What is the mesomorphic iPP? The mesomorphic iPP-HT shows longer regular 3/1 helixes than the crystalline iPP-LT (Fig. 3b). The structure and its formation mechanism of the mesomorphic iPP are considered analogous to those of lyotropic liquid crystals' since the long regular 3/1 helixes should act as the mesogenic segments of liquid crystal. These results suggest that mesomorphic iPP is a liquid crystal like structure formed through a specific kinetic pass.

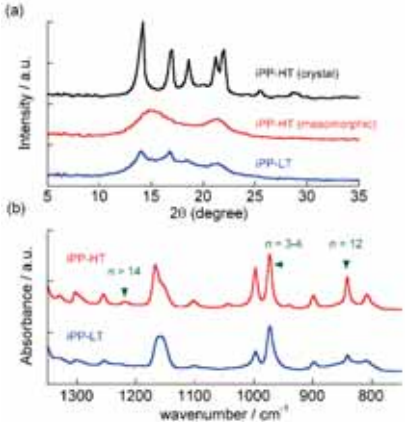

Figure 3. Wide angle X-ray diffraction profiles (a) and Fourier transform infrared spectra (b) of crystallized iPP-HT (black line), the quenched iPP-HT (red line) and the quenched iPP-LT (blue line). *n*: minimal number of 3/1 helical sequence.

Shear Flow - Aiming to Reveal the Formation Mechanism of Fiber Structure, Grant-in-Aid for Scientific Research (B) (2), 1 April 2003 - 31 March 2005.

Kanaya T, Tasaki S, Dynamics of Graft Polymer Chains in Nanometer Scale by Neutron Spin Echo, Grant-in-Aid for Exploratory Research, 1 April 2003 - 31 March 2005.

Kanaya T, Collaboratory on Electron Correlation Toward a New Research Network between Physics and Chemistry, Grant-in-Aid for Creative Scientific Research, 1 April 2004 - 31 March 2006.

Kanaya T, Higher Order Structure Formation in Induction Period of PLA Crystallization and in External Fields, Collaboration Research with Toyota Motor Corporation and Toyota CRDL., INC, 15 January 2003 - 31 March 2006.